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STABLE GROUND TRUTH ARTEFACTS FOR MEASUREMENT VALIDATION FOR 3D SCANNERS

HP INC

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Abstract:

3D printed polymer parts (e.g. PA12, PA11 etc) have a high coefficient of thermal expansion (CTE) and can be hygroscopic. In addition, they may change shape/size subtly over time due to internal stress relaxation. The net result of this is that if a part is to be used to validate a measurement apparatus (3D scanners etc) on real world parts with representative optical surfaces, as opposed to test artefacts which are in the majority made of different (stable) materials, there is a challenge to ensure that ambient conditions do not affect the outcome. We propose an approach that uses a stable 'core' of material that is then covered with a thin layer of the material under test ('veneer').

Ground Truth Artefacts for 3D Optical Scanners

There is a need to establish the accuracy of optical measurement apparatus on real world 3D printed parts. This is due to the potential interaction of the material at the surface e.g. subsurface scattering, specular reflection etc. that can alter the signal/interpretation of the optical scanner and thus make the establishment of precise, real world, scanner accuracy difficult.

Typical specification for part tolerances with polymers is +/-0.2mm (over a 100mm length). Standard precision/tolerance ratio selection requires a measurement accuracy ~ 10 times greater e.g. 0.02mm/20um. Thus, if we now consider being able to appraise an optical scanner that has a target specification of +/-20um. This would require an artefact with an uncertainty of less than +/-2um.

Polymer/plastic materials have a high CTE, for PA12 it is typically 100 ppm/°C. For a part used in the printer calibration which has an 80mm dimension from end to end, for every 1 degree C change in temperature the change in this dimension would be 8um. Clearly this is larger than the 2um goal described above and controlling ambient temperatures even to 1°C is not realistic.

It is common to wrap low grade material with a higher grade thin outer layer - wood veneers, teeth etc, but we have not seen this approach used to overcome the problem of high precision dimensional stability. It is conceivable that a full body polymer test part could be measured by a CMM just prior to scanning but this would require the CMM to be in the same room/location as the scanner and the part not handled significantly.

Description:

A stable core of typically Invar 36 (CTE 1.2 ppm/°C) is covered in a thin layer of the material under test e.g. PA12 that geometrically replicates a test object. In figure 1 shown below, the equivalent 80mm length now comprises 76mm of Invar and 2 + 2mm of PA12. The resulting expansion for 1 degree C is now 0.49um (0.091 + 0.4). The veneers are individual (with clearance gaps where they are adjacent) so as to prevent expansion along the longer dimensions creating a global dimensional movement. The veneers are bonded to the core at strategic locations with a suitable structural adhesive to limit the potential influence of this coupling mechanism at the same time as providing a stable bond between the veneer and the core. There is a proportionate reduction in the effects of moisture and stress relaxation due to the reduction in material. (The invar can be coated in a suitable non-reflective paint so as to reduce unwanted capture data).

Another option is the ability to eliminate the 'sink' or meniscus surface from the artefact. This lipped surface is prevalent on all top surfaces (Z+) of a powder bed fusion print process and creates a complexity for measurement due to its complex shape. This is potentially undesirable when testing the accuracy of the measurement equipment, however because the veneers are individual it is now possible to select all lower (Z-) printed surfaces when building this design.

A CMM or other suitable precision device can be used to establish a ground truth of these artefacts with a suitable procedure/method e.g. multiple sample points/scanning probe that can then be used to compare the scanner results against.

ISO10360-2:2008 specifies that for testing CMM's one test artefact must be made from a material with a higher but known/stable CTE (8-13ppm/°C). This is easily achievable with the proposed design.

This approach is scalable for varying designs and different scales with the limitation that the amount of material in the surfaces/axes to be measured needs to meet the CTE requirements e.g. be thermally gapped.

Advantages:

- Provides a known ground truth artefact for optical scanner accuracy measurement on real world parts without requiring excessive ambient temperature control.
- Scalable/re-configurable depending on scanner field of view and test requirements.
- Option to select surface properties without problematic print process idiosyncrasies.

Fig 1 – Schematic of a simple 'veneered' test artefact:

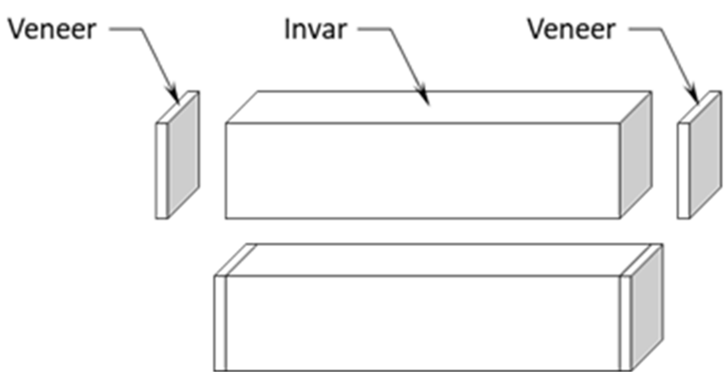


Fig 2 – Schematic of a stepped ‘veneered’ test artefact:

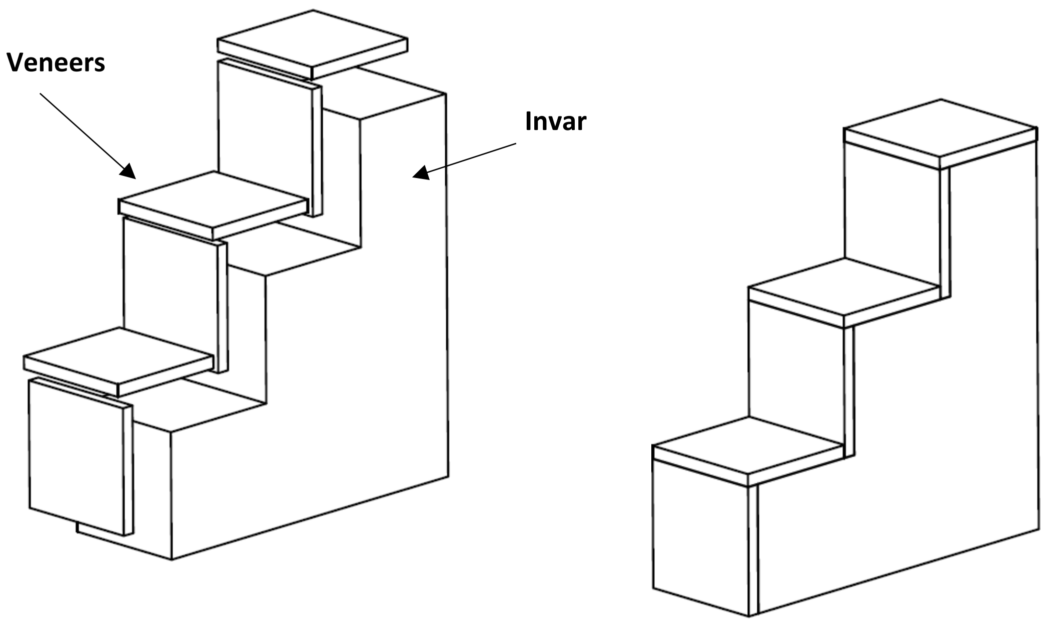
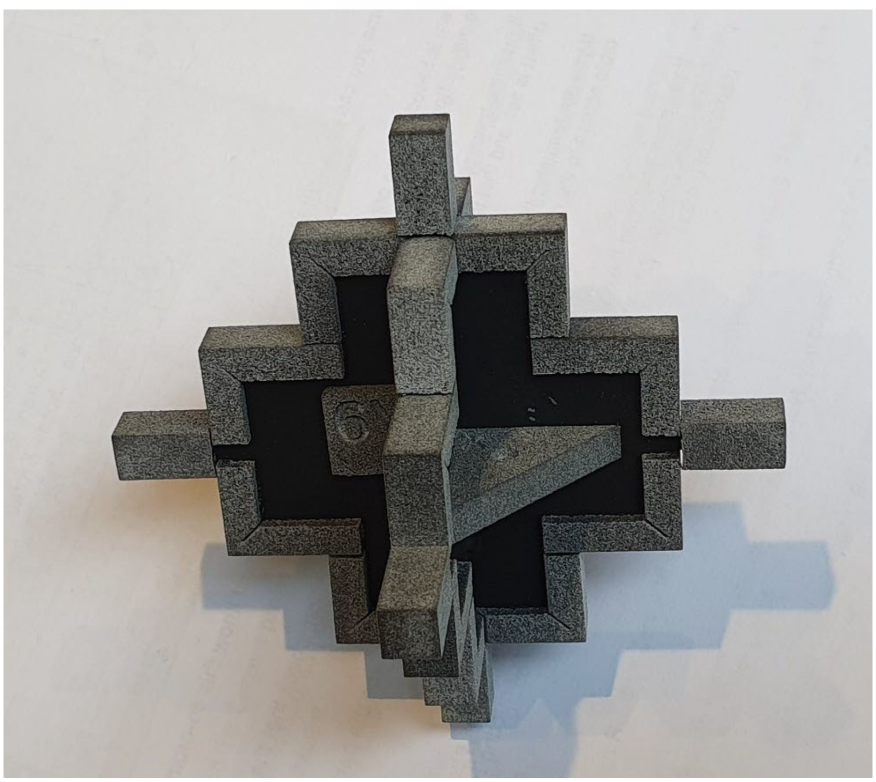


Fig 3 – Assembled Invar 36 ‘core’ + PA12 ‘veneers’



Disclosed by Guy Adams and Lawrence J Gutkowski, HP Inc.